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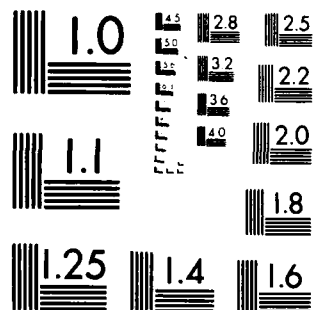
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REPORT

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**CHARACTERISTICS OF A PLASMA-INJECTION-CONTROLLED
DISCHARGE FOR CO₂ MIXING LASERS**

R. McLeary and P.J. Beckwith

ABSTRACT

This report presents the characteristics of continuous electric discharges which have been used in high-power carbon-dioxide mixing lasers. The discharges in nitrogen at atmospheric pressure are stabilised by the plasma-injection technique. Discharge characteristics are presented for a range of discharge dimensions, pre-ionising discharge currents and gas-flow rates. Specific input energies as high as 900 kJ/kg have been achieved.

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REPORT NO.
MRL-R-922

AR NO.
AR-003-904

REPORT SECURITY CLASSIFICATION
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TITLE

CHARACTERISTICS OF A PLASMA-INJECTION-CONTROLLED
DISCHARGE FOR CO₂ MIXING LASERS

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REPORT DATE
APRIL, 1984

TASK NO.
DST 83/038

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KEYWORDS

Carbon dioxide lasers

Gas discharges
Preionisation
High pressure

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ABSTRACT

This report presents the characteristics of continuous electric discharges which have been used in high-power carbon-dioxide mixing lasers. The discharges in nitrogen at atmospheric pressure are stabilised by the plasma-injection technique. Discharge characteristics are presented for a range of discharge dimensions, pre-ionising discharge currents and gas-flow rates. Specific input energies as high as 900 kJ/kg have been achieved.

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CHARACTERISTICS OF A PLASMA-INJECTION-CONTROLLED

DISCHARGE FOR CO₂ MIXING LASERS

1. INTRODUCTION

The development of the plasma-injection technique [1,2] for stabilising continuous electric discharges at high pressure (about one atmosphere) has allowed the construction of a number of high-power CO₂ lasers at MRL [3,4,5]. In these lasers the main discharge is stabilised by the injection of plasma from an array of subsidiary arc discharges which originate on pin electrodes associated with holes in a perforated metal plate. Gaseous nitrogen is injected at sonic velocity through the holes and the ionised or otherwise excited species which form in the pin discharges disperse over the main-discharge volume. The presence of these excited species provides a background level of ionisation in the main-discharge region which inhibits the formation of discharge instabilities.

The first mixing laser [4] based on this technique had a simple open volume formed between two electrodes as the main-discharge region, and achieved specific discharge energies (electrical energy per unit mass flow of gas) of around 130 kJ/kg before the onset of discharge instability. It was subsequently found that the specific input energy could be increased to 200 kJ/kg or more by sub-dividing the main-discharge region so that each pin discharge feeds a volume of circular cross section (Fig. 1). It is probable that the increase in specific energy is due to a flow-velocity profile in which there are no regions of both low gas velocity and high electrical conductivity, such as can occur between adjacent gas streams in open geometries. In practice the required geometry is most easily achieved by the use of glass tubes centered on the pin discharges and of length equal to the main discharge. This arrangement has been used in the latest high-power laser constructed at MRL [5], and has allowed a 50-kW output to be achieved with only a small increase in gas flow compared with that required by the earlier 20-kW device [4].

This report presents data on the voltage-current characteristics and the maximum input power for these discharges. This data, which is presented for a range of discharge parameters, may be used as a basis for the design of high-power lasers utilising this type of discharge.

2. APPARATUS

A schematic diagram of the apparatus used in this investigation is shown in Fig. 1. Discharges were excited in the glass tube situated between the aluminium pin-hole plate and the stainless-steel mesh which form the main-discharge electrodes. A number of pin-hole plates were available with hole diameters in the range 1.4 mm to 2.0 mm. The range of tube diameters was 6 mm to 19 mm and the range of tube lengths was 50 mm to 80 mm. A copper pin was used and pin currents could be varied from 100 mA to 200 mA.

The apparatus was evacuated and filled with N_2 , prior to an experiment. During an experiment the gas flowed into the apparatus through a flow tube and was exhausted directly into the atmosphere through the large-area valve shown in Fig. 1. This arrangement did not allow variation of the discharge pressure, but it has been previously found [2] that a pressure of 100 kPa is close to optimum. Electrical power for the discharges was provided by three-phase, full-wave-rectified transformers and the regulated gas flow was obtained from a commercial high-purity cylinder. The 100-k Ω resistor incorporated in the main-discharge circuit (Fig. 1) acted as a current limiter when the voltage reached a value sufficiently high to cause arcing. At lower voltages the main discharge has a positive slope resistance (Fig. 3 - Fig. 26) and does not require a ballast resistor.

The main-discharge current and voltage, the pin current, the gas flow rate and the pressure upstream of the pin-hole plate were monitored during each run. Experimental runs were limited to durations of five seconds to avoid any heating effects of the apparatus.

3. RESULTS

The experimental results are presented in Figs. 3-26. In all cases the main-discharge pressure is 100 kPa (one atmosphere) and the pressure behind the pin-hole is 240 kPa.

It was found that the results for a given set of parameters were reproducible provided that the cylinder of gas was not changed. Variations of discharge resistance of about 20% were observed with gas from different cylinders. The gas used was commercial high-purity N_2 (nominal purity 99.99%), so the discharge resistance is evidently extremely sensitive to variations in the amount and type of impurity.

The values of the discharge length (L), discharge diameter (D), pin current (I_p) and mass flow rate (m) are indicated on each figure. A vertical arrow on a voltage-current curve indicates that a discharge instability has occurred. Fig. 2 is a key to the results presented in Figs. 3-26 and is included to allow rapid access to results for a particular set of parameters. It can be seen that input powers of up to 850 W in a single discharge are possible at a flow rate of 1.8 g/s (Fig. 16), and that specific energies of up to 900 kJ/kg can be obtained (Fig. 21) at lower flow rates.

4. CONCLUSION

The voltage-current characteristics and maximum power of discharges suitable for use in high-power mixing lasers have been presented over a range of parameter values. In the design of a laser of a nominated power it is desirable to minimise the gas-flow rate, the total pin-discharge current and the total number of discharges, and to maximise the overall efficiency. There may also be some constraints on the maximum acceptable discharge voltage. In general these requirements cannot be satisfied simultaneously and a compromise is necessary. The results presented in this report provide information by which decisions on this compromise can be made and were used in the design of the 50-kW laser described in Ref. 5.

5. ACKNOWLEDGEMENT

The authors are grateful for the assistance of Mr S. Savanah who was responsible for the operation of the equipment throughout this series of experiments.

6. REFERENCES

1. McLeary, R., Beckwith, P.J. and Gibbs, W.E.K. (1974). "Uniform Continuous Discharges and CO₂ Laser Action at Atmospheric Pressure by Plasma Injection". IEEE J. Quantum Electron., QE-10, (9), 649-651.
2. McLeary, R. and Beckwith, P.J. (1977). "High-Pressure Discharge for CO₂ Lasers". Report MRL-R-687.
3. Whitcher, R.E. and McLeary, R. (1976). "The Design of a High-Pressure Multi-Kilowatt CO₂ Laser". MRL Report 646.
4. McLeary, Ross C., Whitcher, Russell E. and Beckwith, Peter J. (1979). "A 30-kW CO₂ Mixing Laser". Report MRL-R-751.
5. Whitcher, R.E. and McLeary, R. (1984). "A 50-kW Electric-Discharge CO₂ Laser". MRL Report to be published.

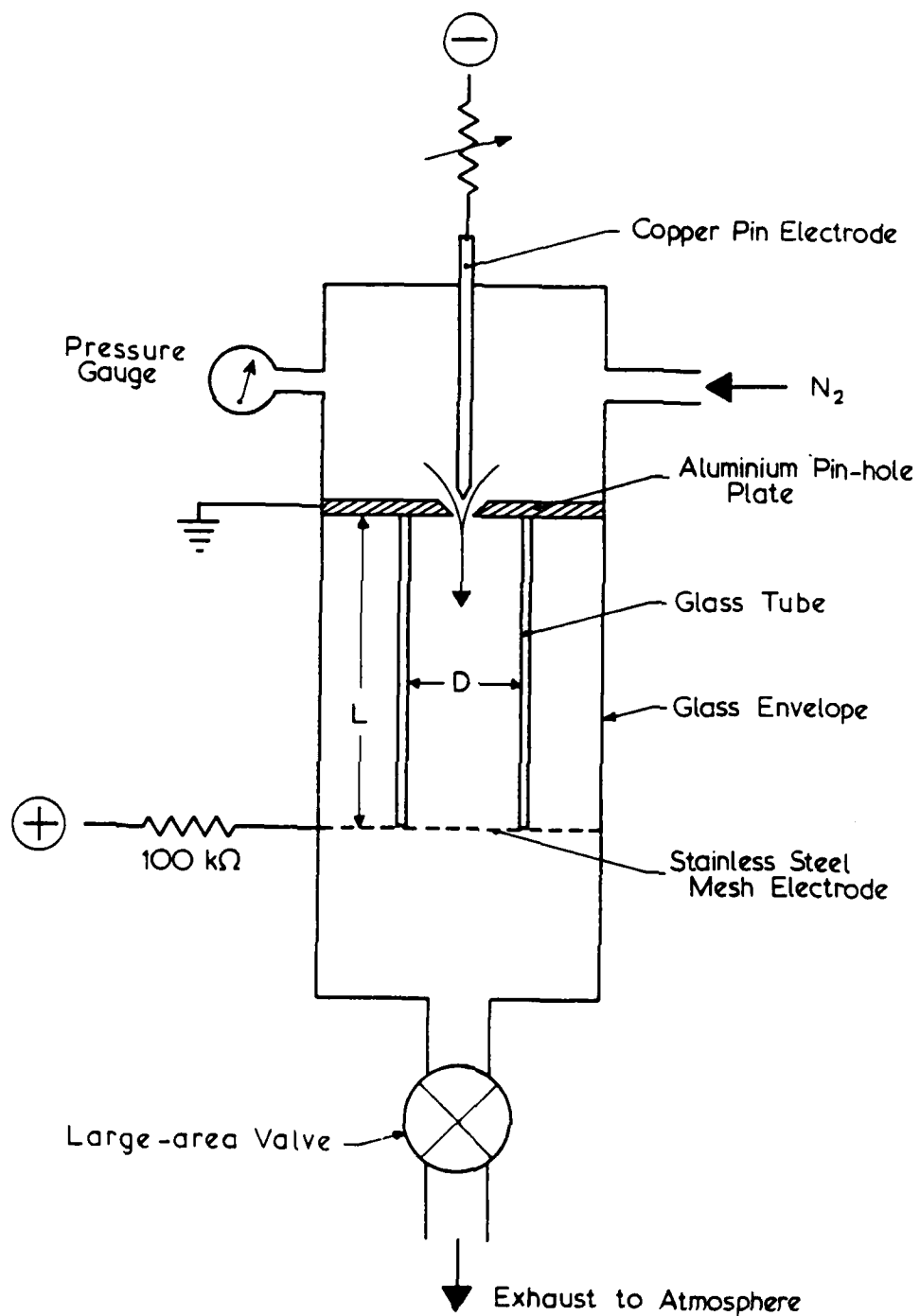


Figure 1. Schematic Diagram of Experimental Apparatus.

L = 50 mm

$\begin{matrix} \dot{m} \rightarrow \\ I_p \downarrow \end{matrix} \begin{matrix} \text{g/s} \\ \text{mA} \end{matrix}$	0.8	1.4	1.8
130	D=11 F3	D=9,11 F4	D=9,11 F5
150		D=6,8 F6	D=11 F7
170	D=11 F8		D=11 F9

L = 60 mm

$\begin{matrix} \dot{m} \rightarrow \\ I_p \downarrow \end{matrix} \begin{matrix} \text{g/s} \\ \text{mA} \end{matrix}$	1.1	1.4	1.8
130		D=6,9 F10	D=9,11,14 F11
150	D=11 F12	D=9,11,14 F13	D=9,11,14 F14
170			D=9,11,14 F15
190			D=9,11,14 F16

L = 70 mm

$\begin{matrix} \dot{m} \rightarrow \\ I_p \downarrow \end{matrix} \begin{matrix} \text{g/s} \\ \text{mA} \end{matrix}$	0.8	1.4	1.8
130	D=9,11,14 F17		
150	D=9,11,14 F18	D=9,11,14 F19	D=9,11,14 F20
170	D=9,11,14 F21		D=9,11,14 F22
190			D=9,11,14 F23

L = 80 mm

$\begin{matrix} \dot{m} \rightarrow \\ I_p \downarrow \end{matrix} \begin{matrix} \text{g/s} \\ \text{mA} \end{matrix}$	0.8	1.4
130	D=11,14,19 F24	D=11,14,19 F25
170	D=11,14 F26	

L = Tube Length

D = Tube Diameter (mm)

I_p = Pin Current

\dot{m} = Mass Flow Rate

Figure numbers are prefixed 'F'

Figure 2. Key to Results Presented in Figs. 3-26.

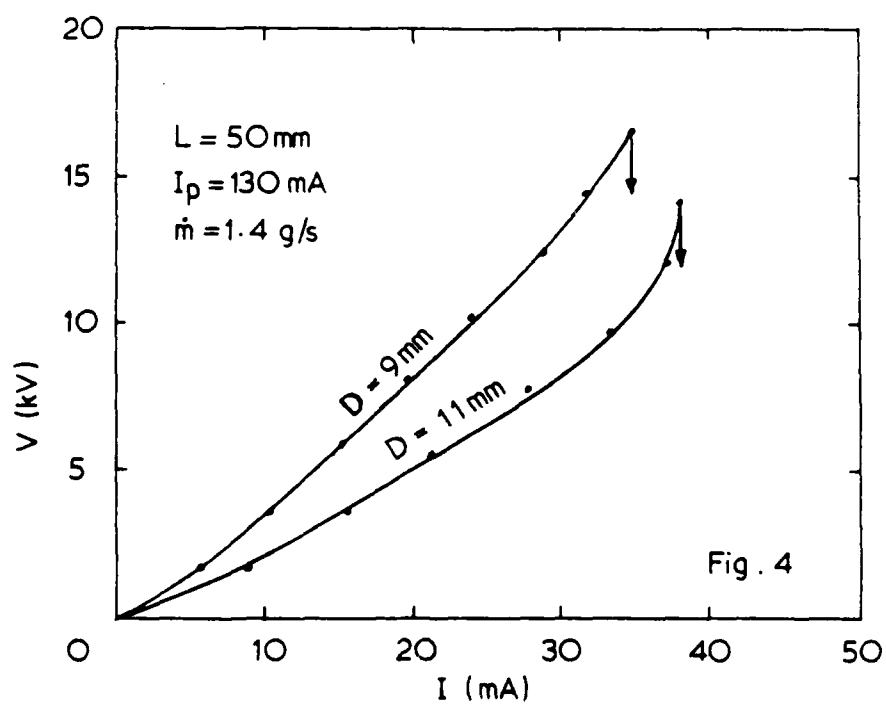
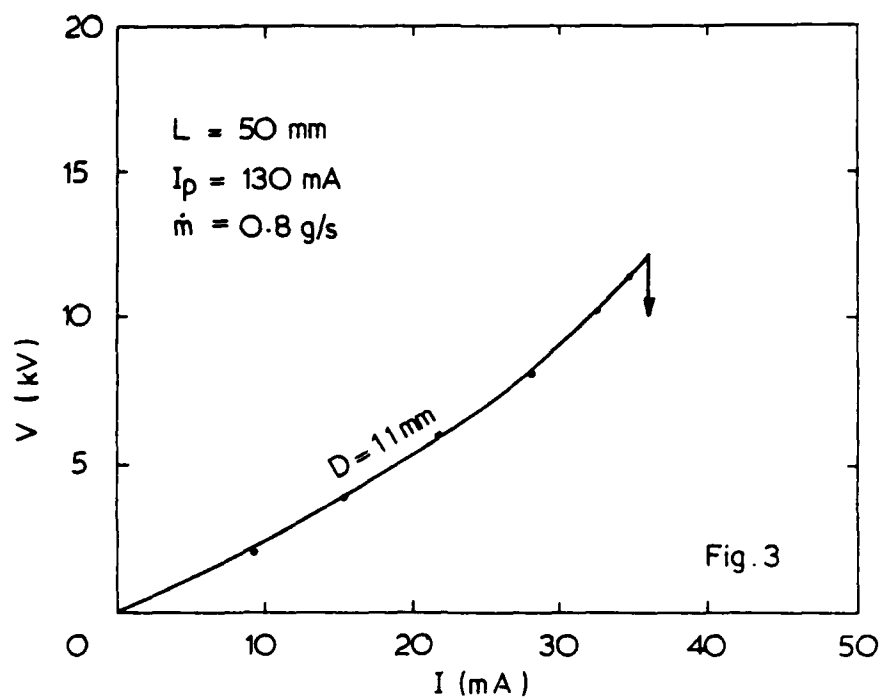


Figure 3 and 4. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

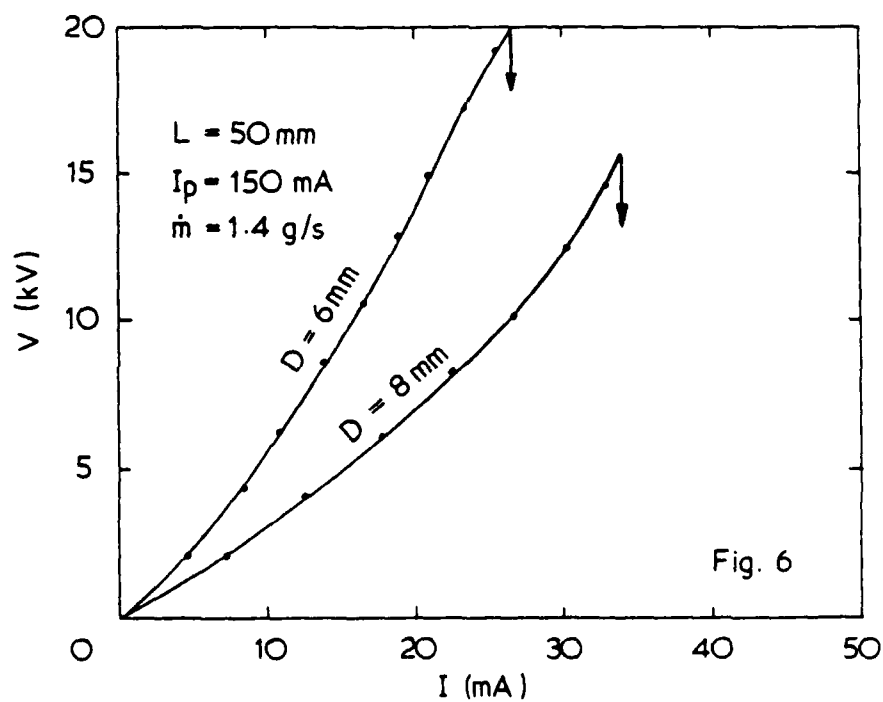
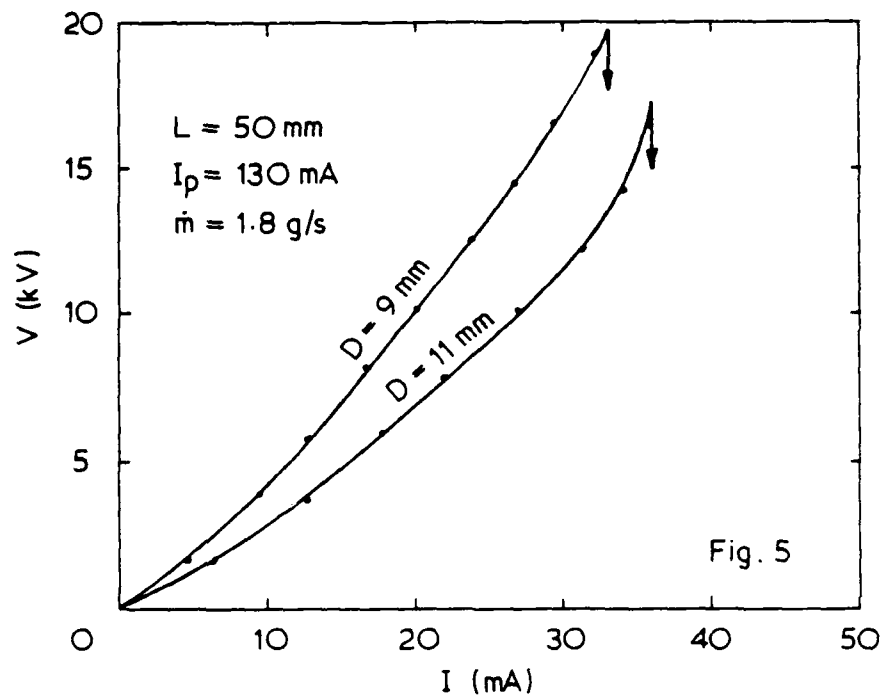


Figure 5 and 6. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

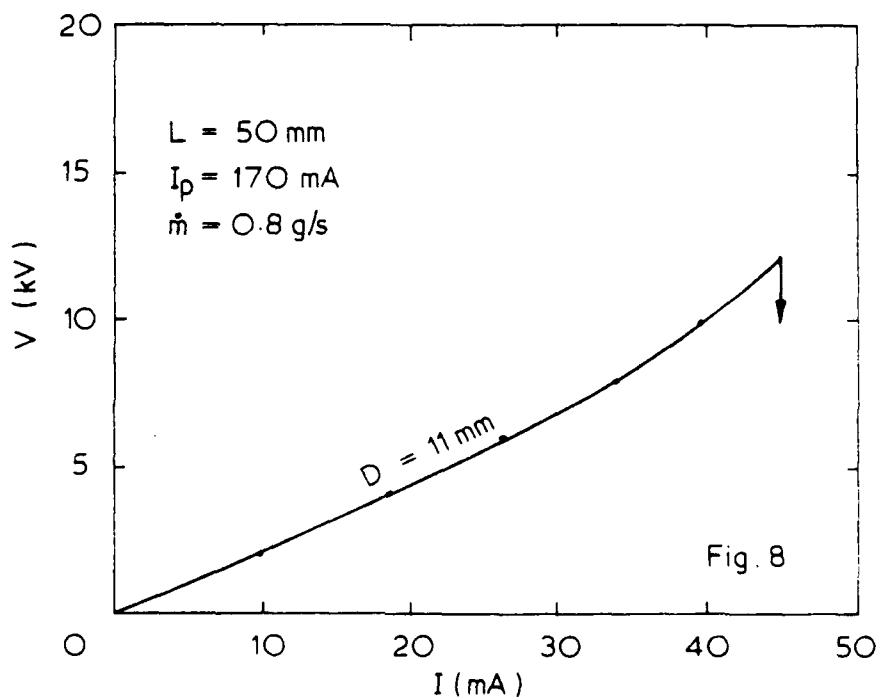
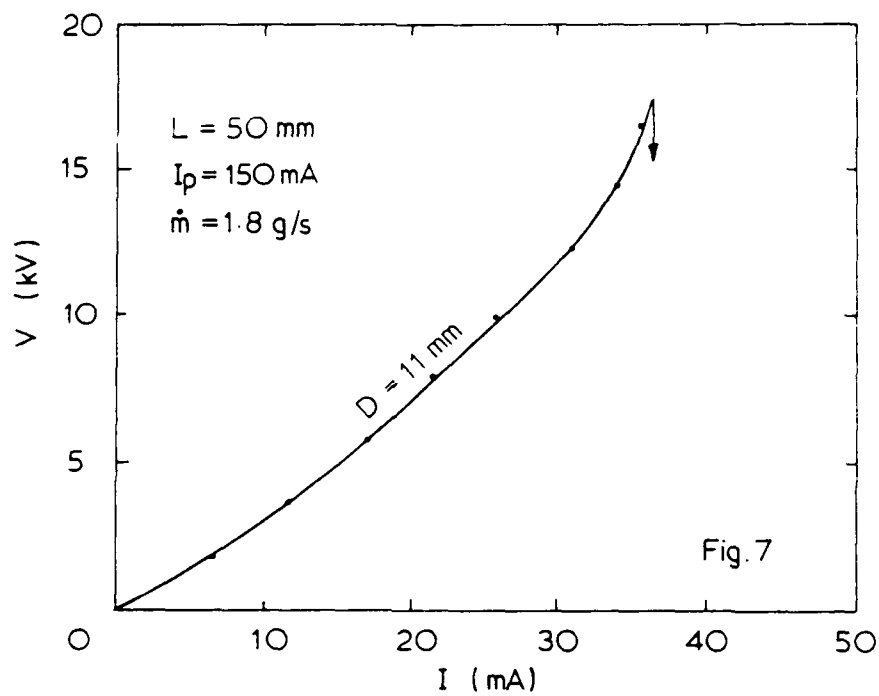


Figure 7 and 8. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

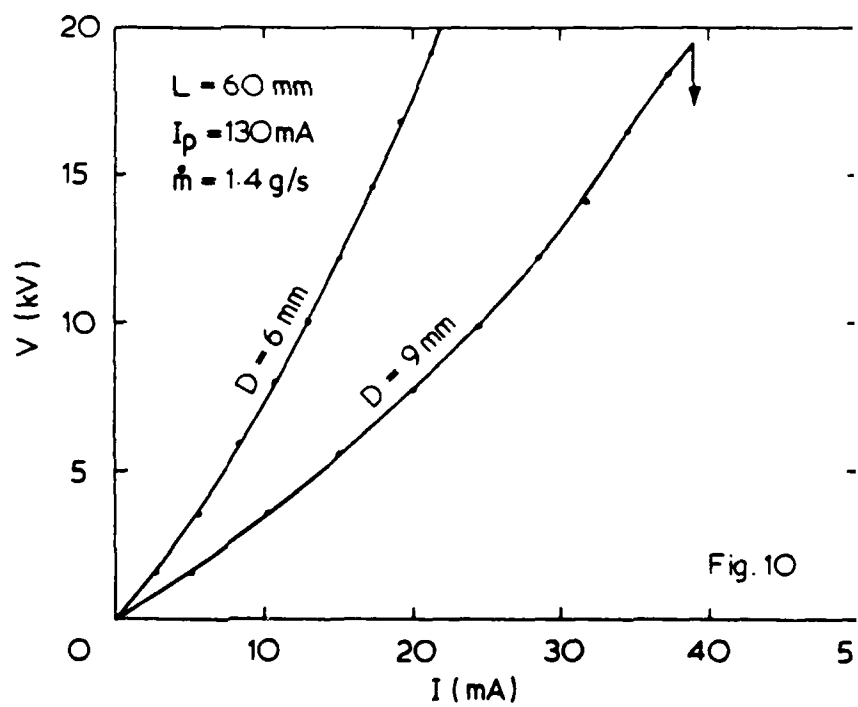
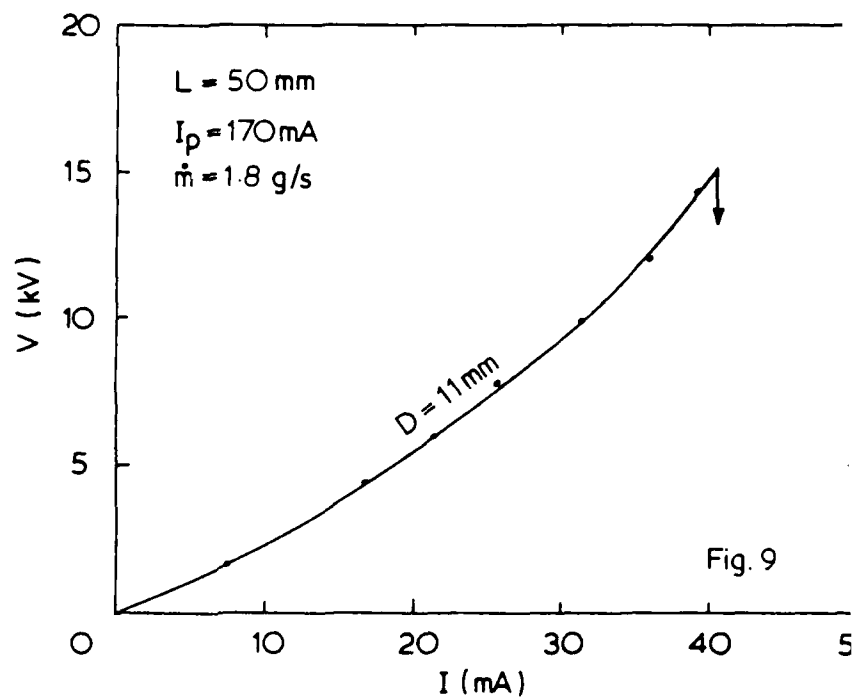


Figure 9 and 10. Discharge Characteristics for Values of L , I_p and \dot{m} shown.

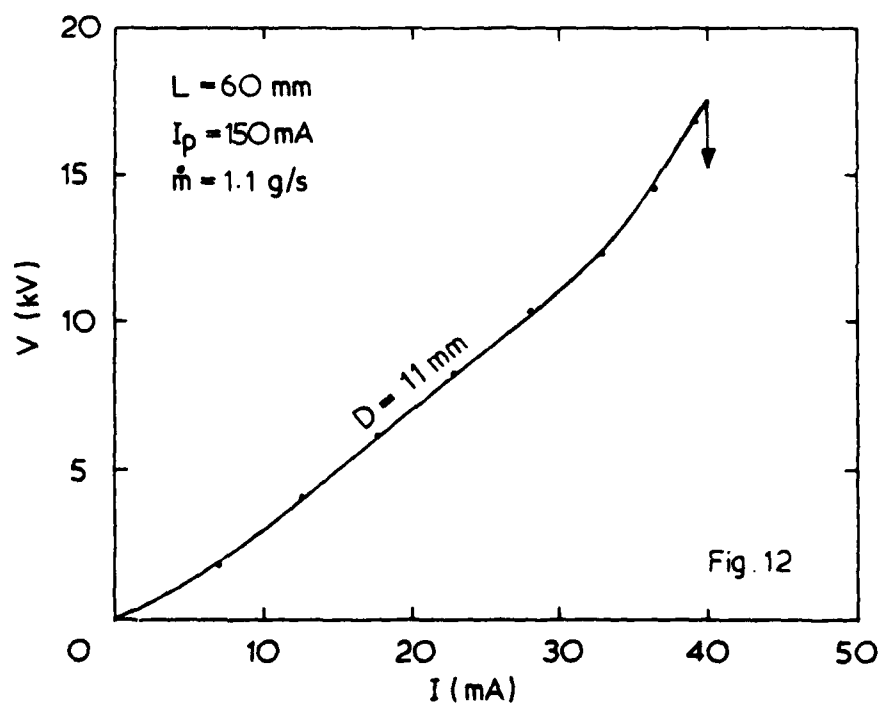
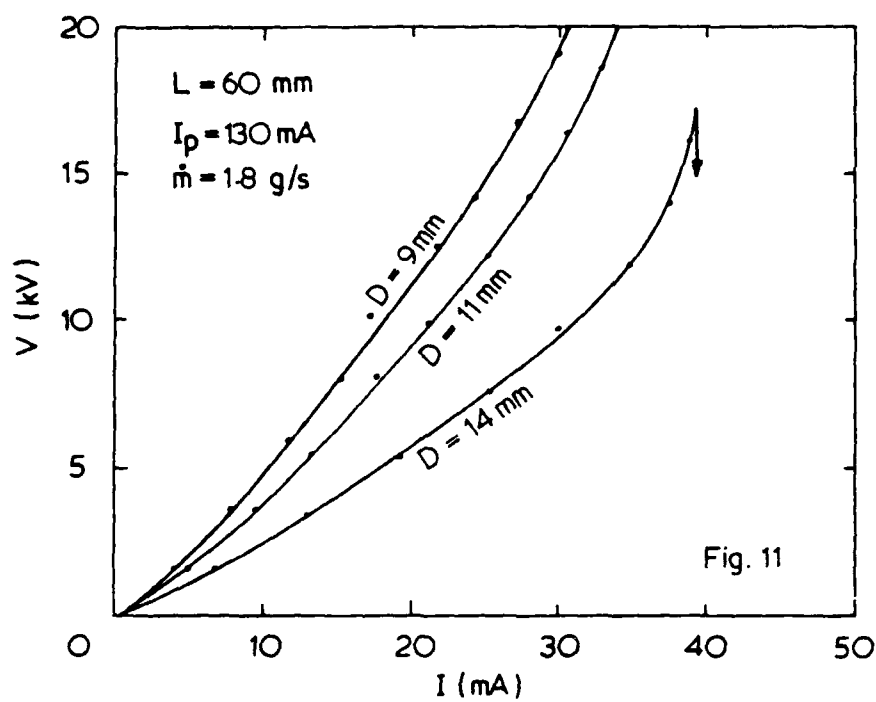


Figure 11 and 12. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

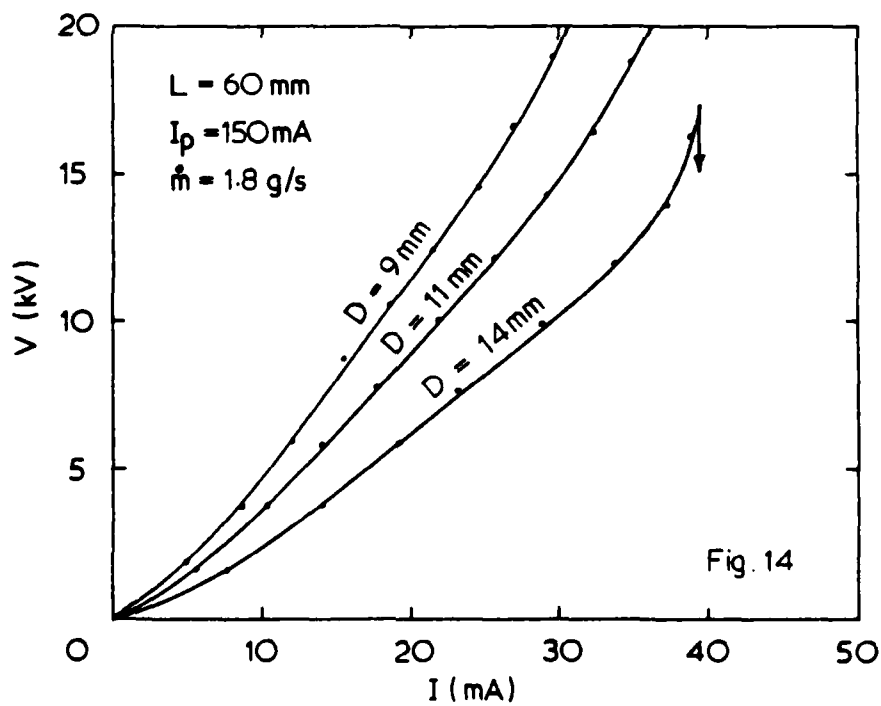
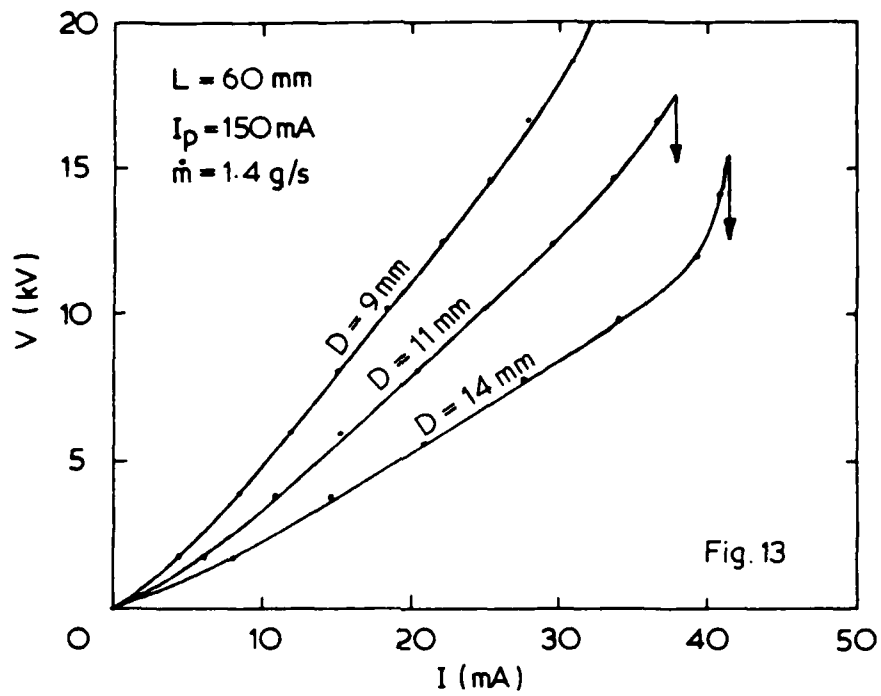


Figure 13 and 14. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

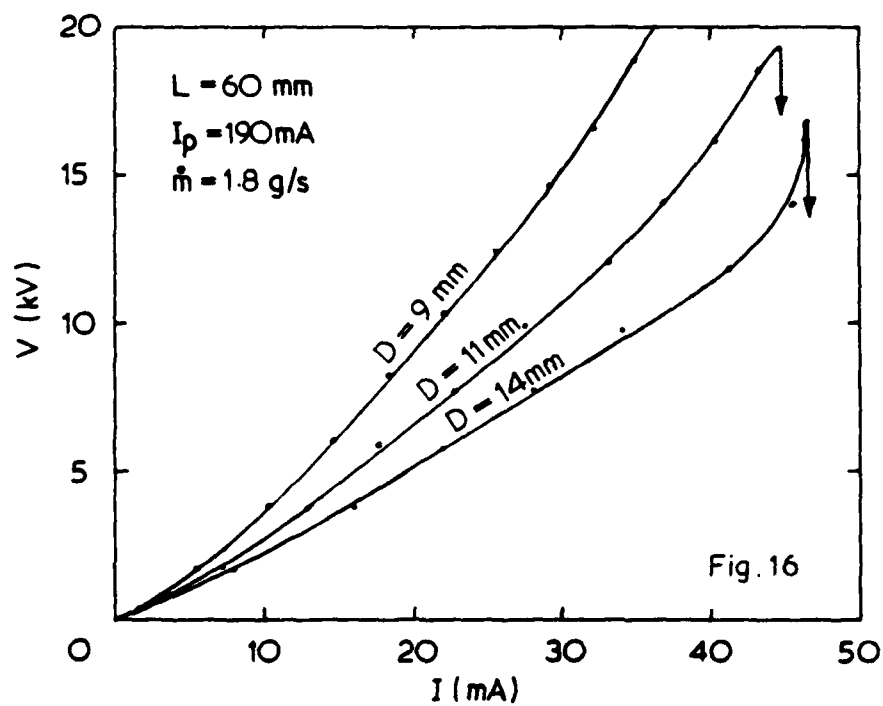
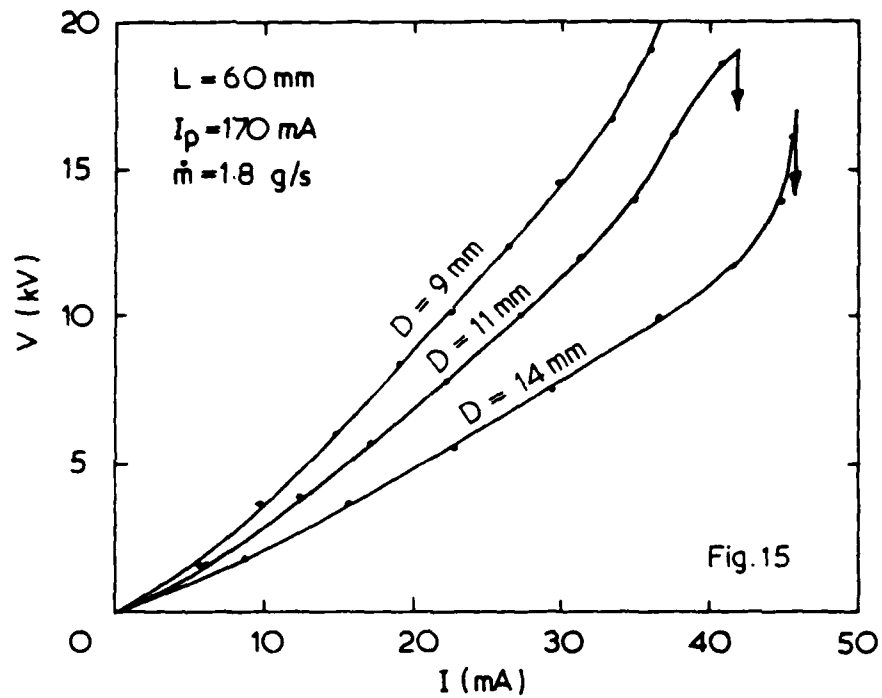


Figure 15 and 16. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

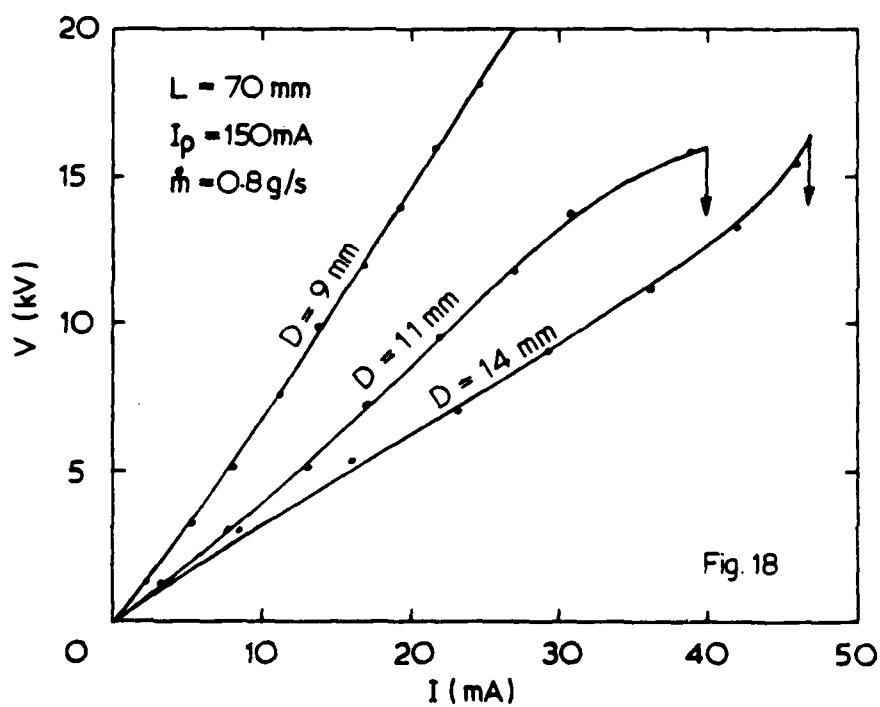
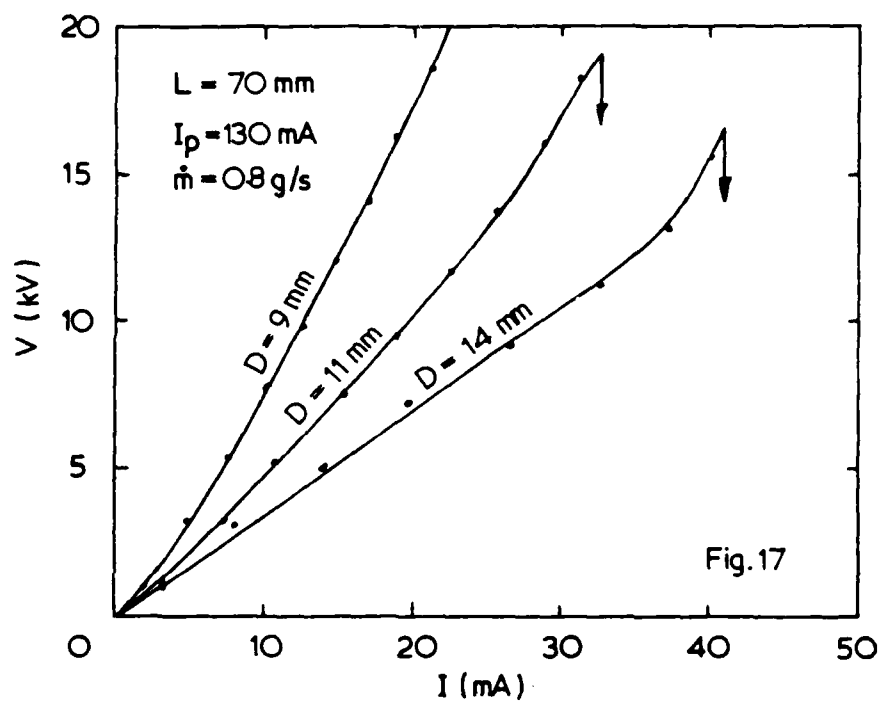


Figure 17 and 18. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

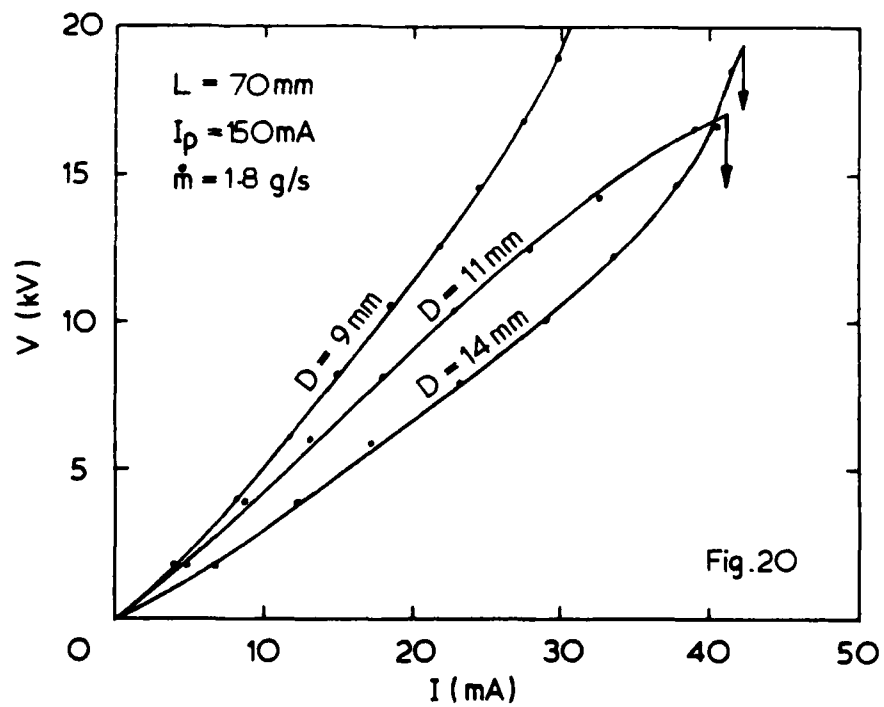
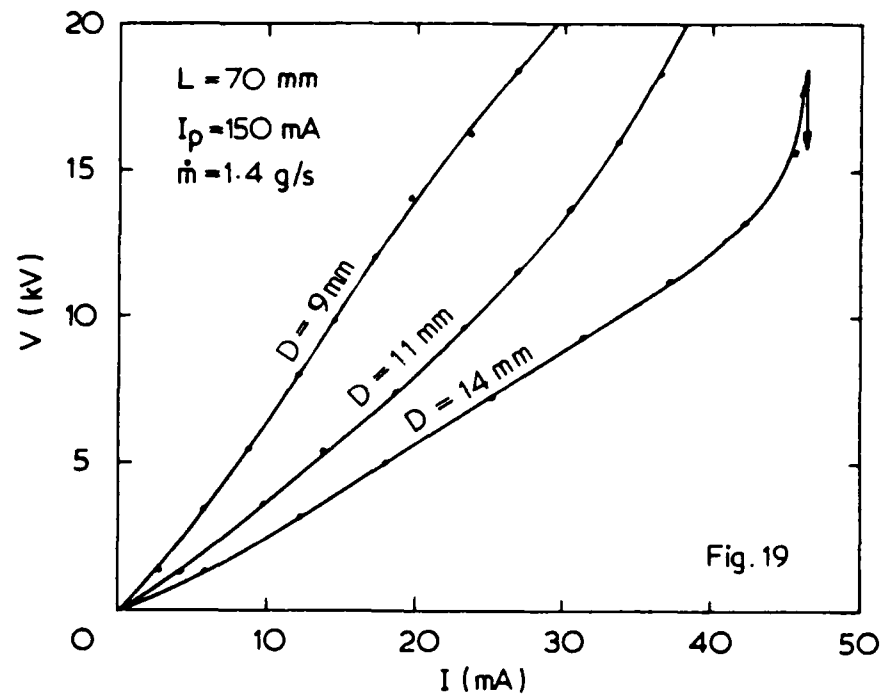


Figure 19 and 20. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

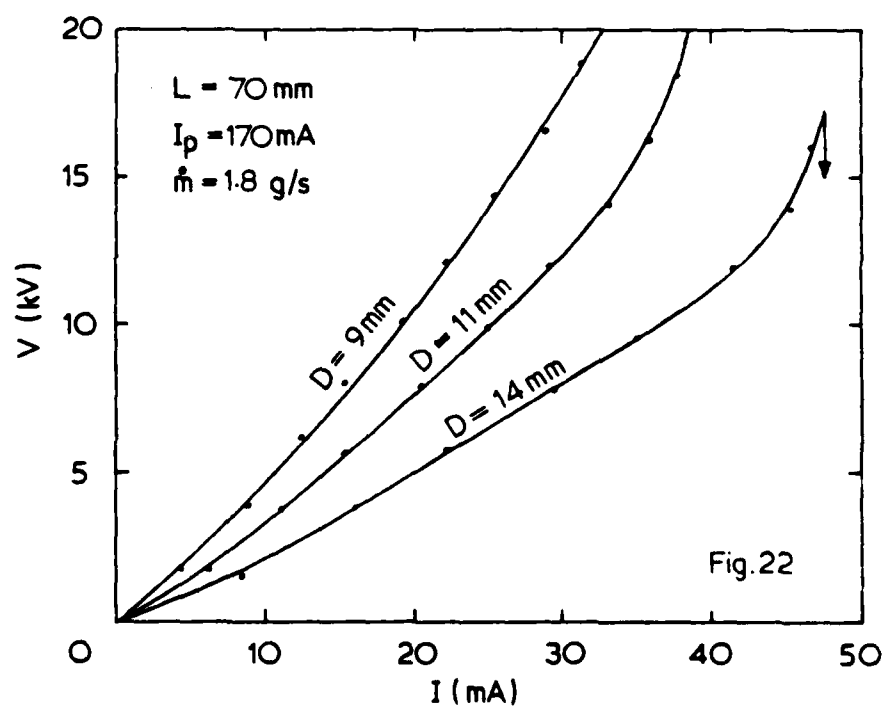
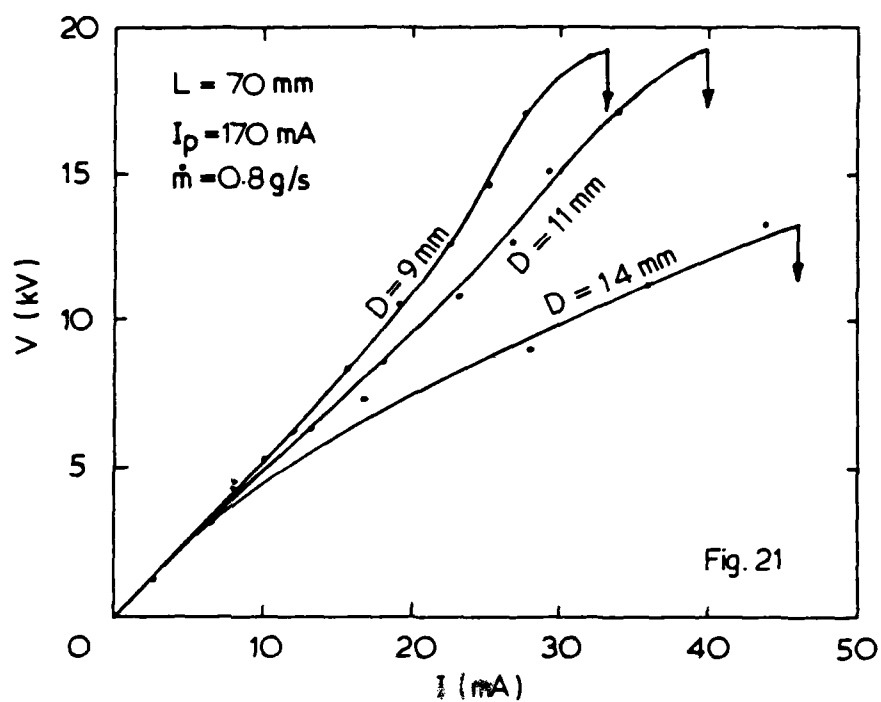


Figure 21 and 22. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

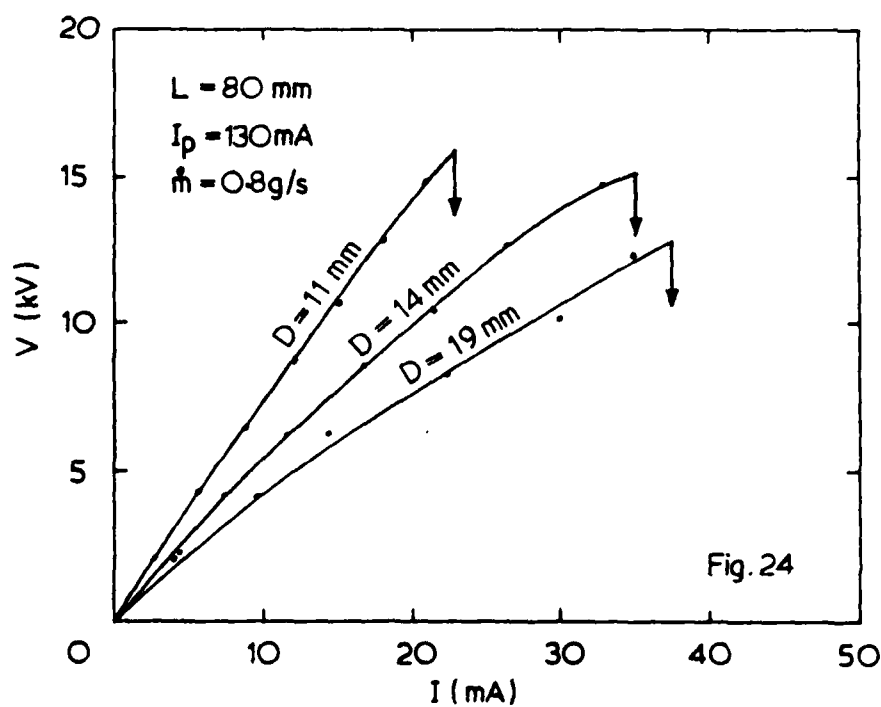
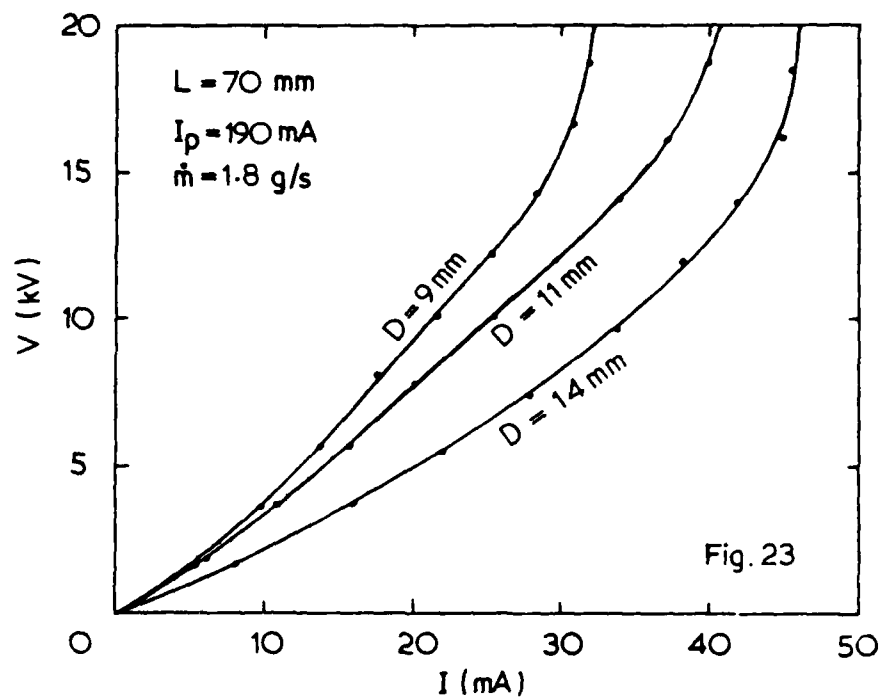


Figure 23 and 24. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

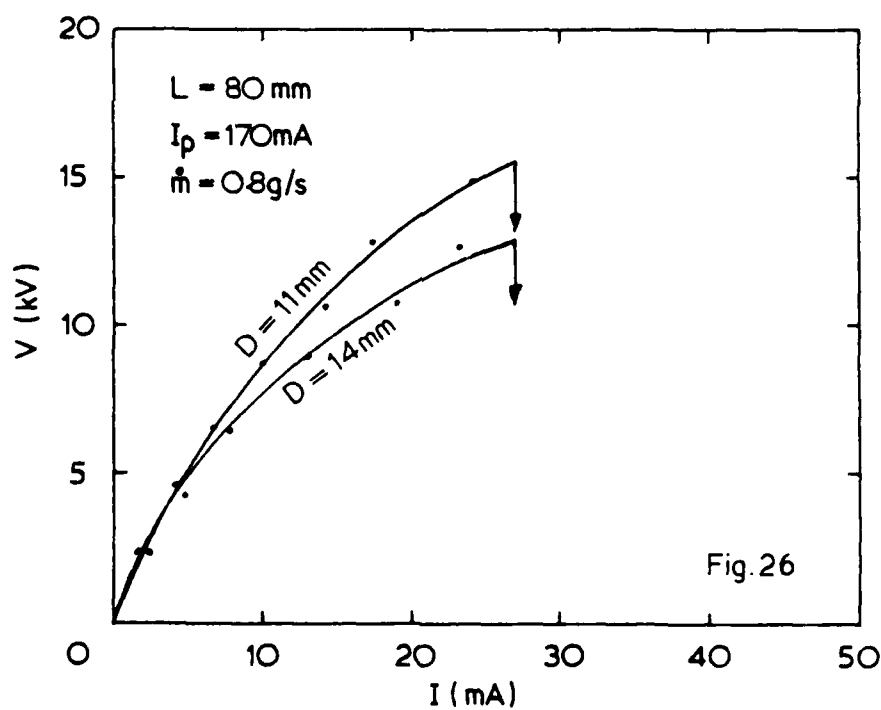
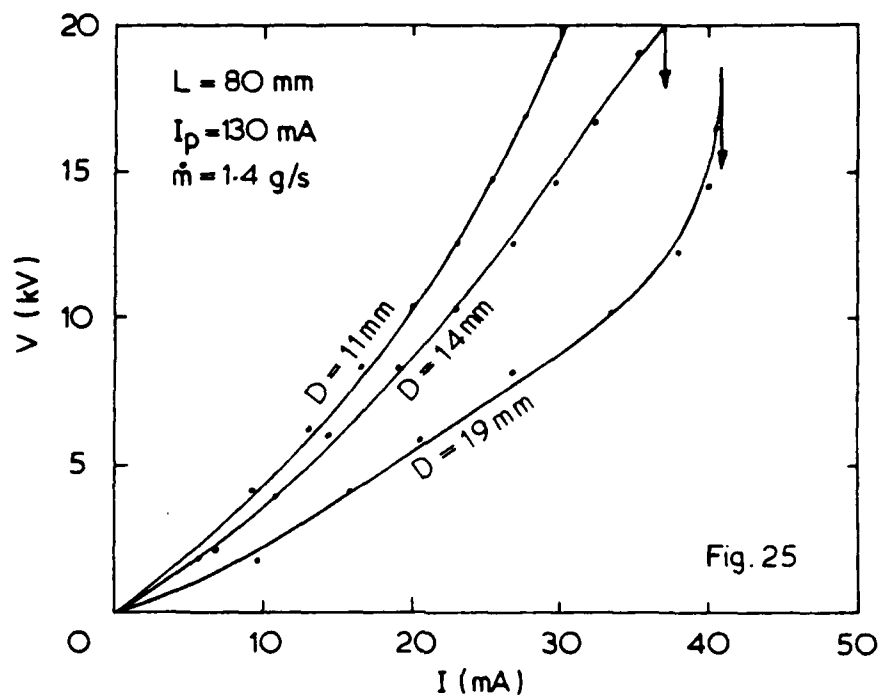


Figure 25 and 26. Discharge Characteristics for Values of L , I_p , \dot{m} and D shown.

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